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Digital Handover of Data from Building Projects to Operation

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Digitale Übergabe von Baudaten in den Gebäudebetrieb

In Dänemark hat die Regierung ein Entwicklungsprogramm mit der Bezeichnung Digital Construction (digitale Bauweise) eingeführt. Eines der diesbezüglichen Projekte befasst sich mit der Festlegung der Anforderungen an den Kundenaufbau im Hinblick auf die digitale Weitergabe der Daten von Bauprojekten an den Baubetrieb. Dieses Projekt begann im Jahre 2004 mit Forschungsarbeiten und Analysen. Hierauf folgte die Erarbeitung eines Vorschlags hinsichtlich der Kundenanforderungen, und es werden Tests im Hinblick auf zwei Bauprojekte durchgeführt. Die hieraus resultierenden Kundenanforderungen werden voraussichtlich ab 2007 für alle öffentlichen Baukunden in Dänemark verbindlich sein. Dieses Dokument enthält einige Ergebnisse des Projektes, wobei der Schwerpunkt auf der anfänglichen Forschung liegt.

Digital construction, ICT, interoperability, building operation, client requirements

1. Introduction

Digital Construction is a development program initiated by the Danish National Agency for Enterprise and Construction in 2003. Behind the program is a vision of a construction process, where all processes from design to building operation are supported by ICT, where all data are digital and where all agents work rationally with the data in the relevant process. The aim of the program is to develop standards to facilitate the exchange and integration of data in IT systems.

The program is organized into six projects. One project focuses on the foundation for digital construction including concepts and classification system. Another project concerns best practice with examples from real life, which documents how digital solutions within the different processes of construction projects can promote efficiency. The remaining four projects all deal with client requirements within the following subject areas: Digital tender, 3D models, Digital handover and Project web.

The client requirements are planned to be compulsory for public construction projects in Denmark from the beginning of 2007. The requirements should as far as possible be based on international standards and it is the intention that the requirement over time become de facto standards in the whole construction industry in Denmark.

Further information on Digital Construction in English language can be found in a brochure on http://www.ebst.dk/file/3095/digitalconstruction_intro.

This paper concerns the project on Digital handover, which is the project closest related to FM. The objective of this project is to be able to reuse digital data, generated in the construction process, in the building operation process and thus achieve enhanced efficiency of the whole handover process. The project started with a competition between consortiums which should include a building client, a knowledge center, a consulting company and a contractor. The winning consortium is called DACaPo and consists of DR (Danish Broadcasting Corporation) as building client, AAU (Aalborg University) as knowledge center, COWI as consulting company and Pihl as contractor.

The project is divided into the following phases:

- | | |
|-----------------------------------|-----------------------------|
| 1. Research and analyses | June 2004-October 2004 |
| 2. Development | August 2004-December 2004 |
| 3. Test, evaluation and revision | January 2005-September 2006 |
| 4. Final evaluation and reporting | October 2006-December 2006 |

The author was employed by DR as deputy project director in the client organization of a major new building project as part of a major relocation and was DR's project manager for DACaPo with responsibility for the research and analyses phase. After appointment as associate professor at the Department of Civil Engineering (BYG-DTU), The Technical University of Denmark from April 2005, the involvement in the project management of DACaPo continues.

The main focus in this paper is on the results from the research and analyses phase. It is explained how these results have guided the development of the proposal for client requirements for digital handover. The proposal is outlined in brief and the experiences from the test and evaluation undertaken so far are described. Further information on DACaPo including a general brochure in English and reports from phase 1 and 2 in Danish can be found on <http://www.detdigitalebyggeri.dk>.

2. Research and analyses

The research and analyses phase was divided into five separate investigations:

- Need for digital data for FM
- Information flow from construction projects to building operation
- Existing ICT tools
- State of the art of digital handover
- Potentials and barriers in relation to digital handover

Each of the five investigations is described below. The different investigations were undertaken concurrently, but the investigation on potentials and barriers started later than the others as this had a more conclusive character. Therefore, this investigation was partly based on results from the others investigations and attempted to set up strategies for the development stage.

2.1 Need for digital data for FM

The purpose of this investigation was to collect quantitative data to clarify the processes that are important in FM organizations and which data are needed to support the different processes.

The data collection was based on a questionnaire to a number of FM organizations. The organizations were selected from members of DFM (Danish Facilities Management Association), DDV (Danish Association for Maintenance) and contacts of the DACaPo partners. The questionnaire was sent to 84 organizations and we received 54 replies equivalent to a response rate of 62%. This was satisfactory particularly as the inquiry took place over the summer holiday period. The sample is not regarded as representative of all FM organizations in Denmark but it is seen as representative for the most advanced FM organizations in both the public and the private sector. Together the respondents are responsible for 25 mio. sqr. m. buildings.

In the investigation FM is divided in four main areas: Building operation, space management, cost management and administration. Most FM organization are involved in all four areas, but it is remarkable, that 87% uses IT-systems for building operation with maintenance planning as the most important task, while only 30% use IT-systems for space management. There is a great diversity in the IT-systems that are used in the FM organizations with ERP-systems and specialized maintenance systems as the most wide spread, while the internationally well known FM-systems like Archibus and Aperture are used by very few organizations in Denmark. Custom-developed systems and combinations of different systems are used widely.

The use of common standards in relation to IT is very limited except for CAD drawings. AutoCAD's file format .dwg is used for data exchange by 78% of the respondents, which is a consequence of the market dominance of AutoCAD among CAD-systems in Denmark. A Danish standard for structuring CAD drawings is used by just over half of the respondents. Most FM organizations have specified requirements for the data to be handed over in relation to finished building projects. Drawings were in most cases handed over electronically as digital data, while other kinds of building documentation in most cases were handed over on paper only.

Almost all FM organizations expect an increased use of digital data in the coming years. The most important data to get in digital form are instructions for building operation and maintenance plans. The greatest barriers for increased use of IT are lack of integration between IT-systems, common standards, human resources and competencies. Contrarily, integration between IT-systems, unambiguous standards, improved data structure and improved data accessibility are the greatest potentials.

2.2 Information flow from construction projects to building operation

This investigation had the same purpose as the investigation of need for digital data except for being of qualitative rather than quantitative character. Furthermore, the investigation of information flow had a broader perspective in relation to identifying

the roles and interests in the information flow of the main parties involved in the construction and building operation processes.

The investigation started with an analysis of interested parties defining client, consultants, contractors and FM organizations as the main interested parties in the information flow. Among secondary parties building authorities and suppliers were included in the analyses as well.

The methods for analyzing information flow were partly inspired from the methodology described as Contextual Design (Beyer & Holtzblatt, 1998). For the construction process each of the main parties' involvement in the overall information flow as receivers, producers, elaborators and deliverers of different kinds of information carriers were analyzed.

As a result the construction process was divided in three different processes in relation to information content:

- Project technical processes – concerns information specifying the product to be constructed
- Project administrative processes – concerns information controlling the process of designing and construction
- Operation technical processes – concerns information specifically needed for building operation

For the building operation process the investigation included sequence analyses of 10 typical cases, for instance maintenance planning, energy and environmental management, rebuilding and rent administration. For each case the activities were analyzed in 10-20 steps including data need and use of ICT.

Following the analyses of information flow in construction processes and data need in typical operational processes a mapping of the information carriers from construction projects that support the building operation were undertaken. The information carriers were classified in document classes and types. The result was a preliminary identification of the data need for digital handover.

Figure 1 shows a schematic overview of the information process in a construction project and the data need in building operation. Only a limited amount of all the data produced during construction projects are relevant for building operation. Most of the information from the project administrative processes is not relevant for building operation and only part of the information from project technical processes – mainly as-built data – are relevant for building operation. All information from the operation technical processes is of course needed in building operation. But it is important also to notice, that new information is created during building operation.

2.3 Existing ICT tools

The purpose of this investigation was to collect information on existing ICT systems used in construction projects and in FM organizations to make sure that the client requirements could take the current technical possibilities into account.

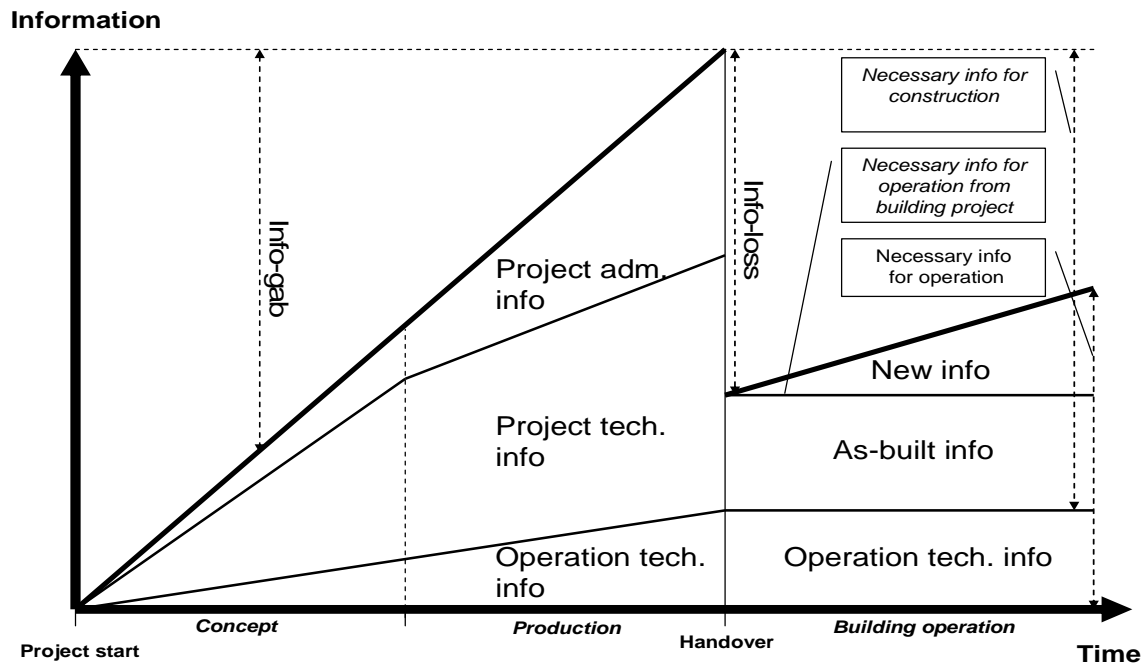


Figure 1. Information from construction to building operation

The investigation was undertaken as two parallel questionnaire surveys among suppliers of IT systems for construction and building operation respectively. The IT systems for construction covered CAD systems and applications for these, while the IT systems for building operation covered various types of FM systems. The questionnaire included questions on numbers and distribution of licenses, functionalities, data model, classification, exchange formats and development plans for the systems.

The general picture of the IT systems for construction is that the technical possibilities for object oriented design and exchange via the international IFC-format is available to a much higher degree than actually used in the Danish construction industry. However, the inquiry does not give information on how far these functionalities are developed. Practical tests have for instance shown that exchange via IFC is more complicated than expected from system supplier's information.

Most of the FM systems are capable of handling object oriented data but import of data must in most cases be based on the relatively "unintelligent" ASCII-format. Only few FM systems can import data in IFC format.

2.4 State of the art of digital handover

The purpose of this investigation was to create an overview of the present situation in relation to digital handover. The investigation included a literature review of publications, standards, guidelines and projects related to digital handover in Denmark and internationally. Furthermore, information on the current practice of digital handover from a number of recent construction projects in Denmark, which the DACaPo partners have been involved in, were collected and analyzed.

The investigation points at the importance of the changes of focus which occurs during construction projects from a functional focus in the early stages to a physical focus during production and again the change to a more diverse focus during building operation. Maintenance is for instance characterized by a physical focus while space management is characterized by a functional focus.

Another conclusion is that FM organizations are showing increased interest and awareness in specifying and receiving data from building projects. However, major parts of the data are needed solely for documentation of the building project without much active usage during operation while other data are needed for a more active usage with updating during the operation process.

There is at the moment no commonly accepted standard for digital handover. The concept of digital handover also has a lot of different interpretations. It is important to develop a model for digital handover based on delivering data according to a common standard and importation by use of a general accepted exchange format from the construction companies' IT systems to the FM systems without the need of manual manipulation of data.

2.5 Potentials and barriers in relation to digital handover

The immediate aim of this investigation was to point out the potential advantages by introducing a standardized client requirement for digital handover as well as the impediments for such a development to be successful. However, the more profound purpose was to develop strategies and criteria for the further project work with developing a proposal for client requirements.

The starting point was a literature review of international investigations into the use of ICT in construction and building operation. Two investigations were of particular interest. One of these was an American cost analysis of inadequate interoperability in the U.S capital facilities industry (Gallaher et al, 2004). The analysis concludes that the annual cost of inadequate interoperability was as much as \$15,8 billion which is equivalent to 4% of the annual value of construction. Two-thirds of the cost is borne by owners and operators although the cost is mainly caused by failures to manage activities during the previous phases in the construction process.

The other investigation concerned the usage of ICT in a number of European countries undertaken by a group of German researchers (May, 2004). This investigation points out a number of strengths and weaknesses in relation to the European market for CAFM. Compared to the American investigation the results of the German investigation indicate a more positive development in Europe. A common result is that the main barriers for the development are not of a technological nature.

Based on the international investigations and the earlier mentioned questionnaire surveys a strategic analysis of digital handover was undertaken by use of a modified SWOT methodology. This method is usually applied in relationship to an existing product or company. In our case we were analyzing a possible future product – a client requirement for digital handover. Instead of analyzing actual weaknesses and

strengths in relation to this product, we used the analysis to define the design requirements for this product to prove successful.

Among the results were the following requirements for usability:

- The solution must be flexible so needs of all building types and FM organizations can be accommodated but according to the same general principles
- The solution must be easy to use and adaptable to most IT systems
- The solution must be easy to implement as client requirements in the briefing stage and should be an integral part of the clients contracts with consultants and contractors
- The solution must be easy to overview and use for consultants and contractors

Another important requirement, related to the state-of-the-art and possibility to future advancements, was that object orientation should be possible, but it must be possible to use the solution without working object orientated. This led to a two track strategy as explained below.

The investigation also included a cost/benefit analysis to evaluate which parts of the data identified in the investigation of information flow, should be included in the solution. The criterion was that the solution should only include processes and document types, if they would create added value seen over both the construction process and the operation process. Due to different needs from different types of FM organization this led to a proposal of a mandatory basic data package and 4 optional data packages, which the individual FM organization could choose to include or not. This was later modified as explained below.

The general conclusion from the investigation was that there are clear advantages for FM organizations by using digital handover. In order to benefit fully from digital handover, one of the challenges is to be more model-oriented in construction projects. As a precondition, construction projects should be developed from document-based towards model-oriented projects.

3. The proposed solution for client requirements

The solution consists of a requirement specification which can be used as a tender and contractual document by the client with the addition of some project-specific information and choices. The requirement specification defines the form, content and extent of the digital data that the client/FM organization wishes to receive at the end of a project. The requirements were supplemented by separate guidelines for clients and FM organizations and for consultants and contractors.

The processes in relation to digital handover are illustrated in figure 2. The core of the solution is a data model. The data model specifies the structured form that the data should have when handed over to the FM organization and it is built up based on the FM organization's need for data during building operation. The data model is object-oriented and consists of a number of building objects as shown in figure 3.

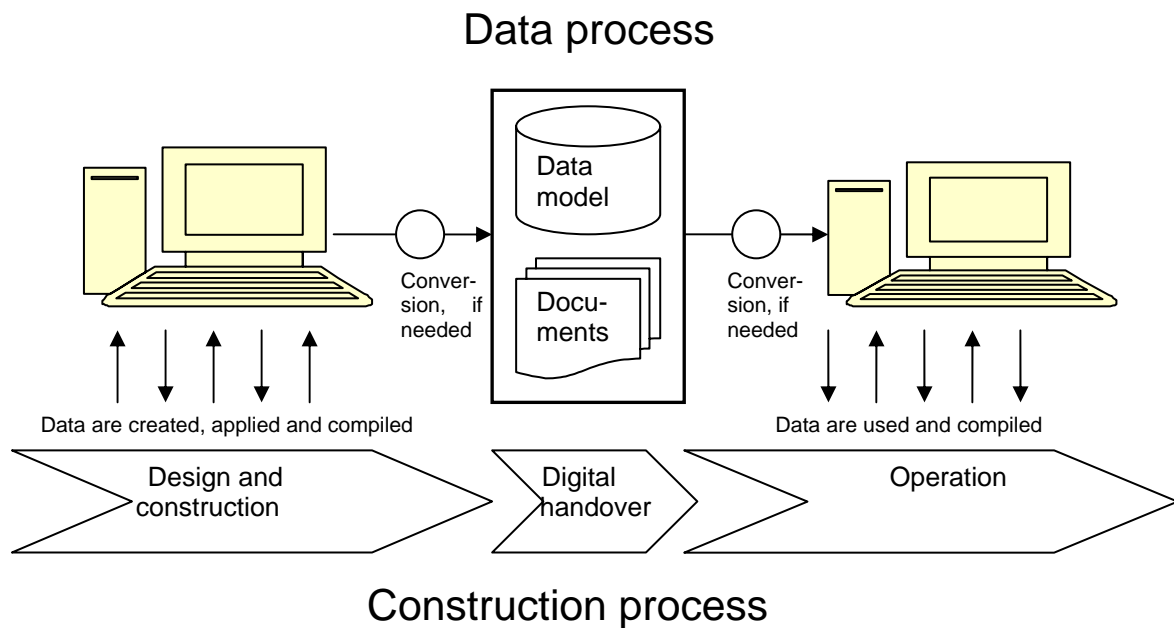


Figure 2. Processes in relation to digital handover

The relation between building objects is specified for each and the content of the data (attributes) are specified. Additional general data objects are described for the building objects. All documents and drawings relating to the data model are divided into document classes and types and are marked with metadata that give different information about the document/drawing like author, date of revision, etc.

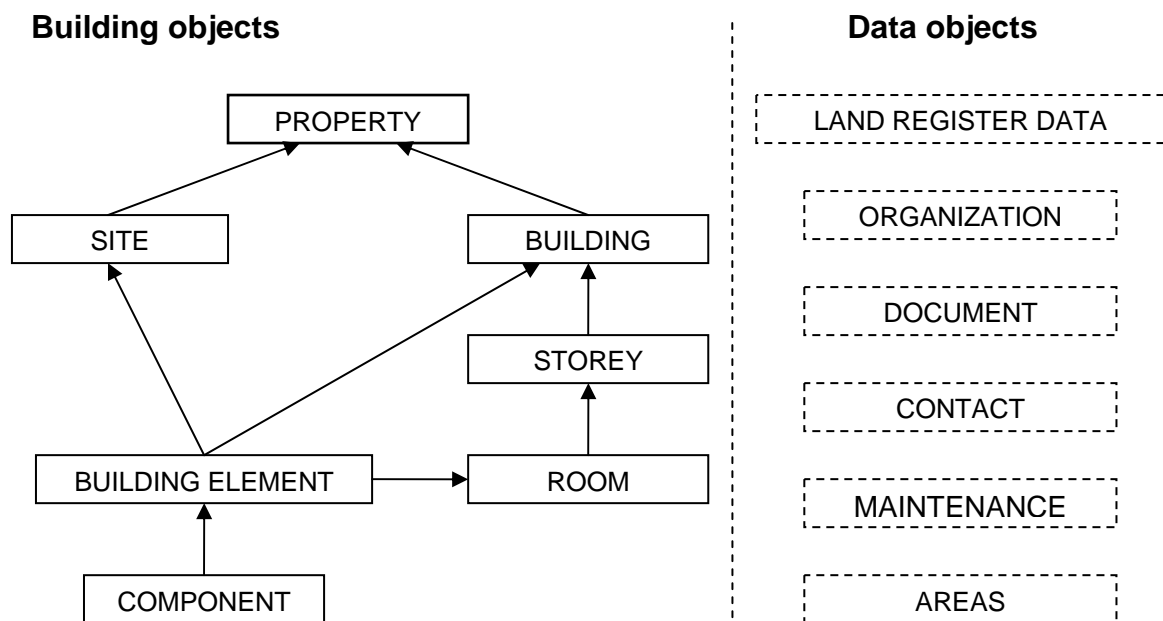


Figure 3. The structure of the building objects of the DACaPo data model

For entering data in the data model either exporting from CAD systems in the international IFC format or a tool developed by DACaPo can be used. The tool generates digital data in DACaPo.XML format, which can be entered in the FM organization's ICT systems. The DACaPo.XML format is defined so that it corresponds to the highest possible degree to the structure in the XML implementation of IFC called IFCXML.

The two-track strategy implies that the client in each case defines the extent of the data model and the degree in which data should be delivered as documents in separate files.

4. Preliminary evaluation

The solution has been presented and got feed-back at a workshop in January 2005 with participation of people involved in Digital Construction and it has been tested in the tender and design phase of one construction project during 2005. From the feed-back and evaluation of the test, the solution has been revised in September 2005. The revised solution will be tested in another construction project in 2006 before a final revision.

The main results of the feed-back and evaluation were:

- The solution was too complex and difficult to understand
- The options for additional data packages could be changed to be mainly compulsory
- The degree of detailing of information of building elements should be specified
- The guidelines should be edited into one document with different columns for clients/FM organizations and consultants/contractors respectively

The revision has attempted to accommodate these comments by simplifying the requirements as much as possible. The options between data packages and the degree of detailing has as far as possible been changed to objective criteria in relation to the specific type of building project. For instance, information on organization of the building on different users is only implemented in buildings for renting out. Furthermore, detailed information should only be given on building elements with movable parts or need for maintenance and/or cleaning specified by the contractor/supplier in the five year period of guarantee, which is compulsory in Danish building contract conditions.

Figure 4 shows the revised list of document classes and types. A number of these can be handover over as part of the data model instead of as separate documents.

5. Conclusions

Digital handover is a part of developing an improved relation between construction projects and building operation. It is an important aspect of making FM more efficient,

but it can also be a tool to make clients, consultants, contractors and public authorities more aware and interested in the activities and needs of the FM organization.

Document class	Document type
Project	General description
	Descriptions of works and parts
	Authority applications/permissions
	Quality defects listings
	Descriptions of functions
	2D-drawings, as-built: Main drawings and diagrammes
	2D-drawings, detailed design: Details drawings
	3D-models, as-built: Geometry of buildings and installations
	3D-models, detailed design: Details models
Operation	Instructions
	Garanties/permission to use
	Data sheets
	Maintenance plans
	Component sheets
	Commissioning reports
	As-built photos
Economy	Operation budget
Space	Areas
	Room sheets

Figure 4. Documents in digital handover

It is interesting, that the project on digital handover is one of the first public supported Danish research and development project related to FM. The research has as a side effect provided more general knowledge about FM organizations.

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For reports etc. from DACaPo, see: <http://www.detdigitalebyggeri.dk>